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Incinerator Technology, Operational Performance and Healthcare-Facility Hierarchy in Kano Metropolis, Nigeria

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ABSTRACT
The study aims examined which incinerator technology, operational performances are in use at government healthcare facilities in Kano Metropolis and whether incinerator category tracks hospital tier. Nine facilities spanning primary, secondary and tertiary care were purposively sampled. Data came from a structured questionnaire (131 valid responses) and direct observation at each site. Brick or locally fabricated incinerators accounted for 73.28% of responses, single-chamber units for 16.03%, and double-chamber or high-technology systems for the remaining 10.69%. Hospital tier and reported incinerator category were significantly associated at the individual-response level ($\chi^2 = 34.75$, df = 4, $p < .0001$, Cramer's V = 0.364; Spearman's $\rho = 0.375$, $p < .0001$), although the 131 responses were nested within nine facilities and the result is therefore treated as descriptive rather than as a stand-alone facility-level test. The research relies primarily on the facility-level pattern and on direct observation. Site visits confirmed that double-chamber units were concentrated in tertiary facilities, brick/local units predominated elsewhere, but also surfaced a functional-operational paradox: three of the nine facilities had incinerators out of service for technical repair at the time of observation, including MMSH, the highest-volume facility in the sample by both patient turnout and waste generation. The findings describe a pattern of structured heterogeneity in which incinerator technology tracks hospital tier, while operational capacity remains uneven across and within tiers. The results offer exploratory, facility-level evidence for tier-differentiated design, maintenance and monitoring standards.

Keywords: Healthcare Waste Management, Incineration Technology, Hospital Hierarchy, Institutional Theory, Kano Metropolis, Structured Heterogeneity

INTRODUCTION

Healthcare waste covers a wide range of clinical and medical materials, including human tissue, blood products, pharmaceuticals, microbiological samples, sharps, dressings and other hazardous items. Where it is poorly managed, the consequences include infection, injury, and contamination of soil, groundwater, surface water and air (WHO, 2020). Managing it well is not simply a matter of collection and disposal, however; the technologies chosen for treatment, and how well they are operated, depend just as much on institutional capacity, financial resources and governance as on technical design.

Incineration remains the most widely used treatment option. As a high-temperature dry oxidation process, it converts organic and combustible waste into inorganic residues and can reduce mass and volume by 85–90% (WHO, 2019). Combustion that is poorly controlled, though, produces toxic air pollutants and hazardous ash, which is why design, operation and residue management all matter (Patel et al., 2024; Chartier, 2014; Kenny & Priyadarshini, 2021; Zhao et al., 2021). In practice, the technology a facility settles on has a direct bearing on environmental and public-health outcomes.

In Nigeria, incineration is favored for its ability to destroy pathogens and cut waste volume, yet weak design and management often undo these benefits, with real consequences for the environment and public health (Adama et al., 2016). Previous research in Kano has concentrated on healthcare-waste management practices, such as segregation, handling, storage and disposal, at individual facilities or within single tiers of the healthcare system (Yakubu et al., 2023; Imam et al., 2019; Sani et al., 2021; Rn & Yahaya, 2014; Omoleke et al., 2021; Danjuma et al., 2026). National-level studies have established that incinerators are unevenly distributed across the healthcare hierarchy, with tertiary facilities more likely to have them (Ezirim & Agbo, 2018; Gage et al., 2016). A recent single-facility study at Aminu Kano Teaching Hospital found that the hospital relies on an outdated incinerator without a scrubber system, raising concerns about emission control (Ibrahim & Liman, 2025), while another study confirmed that incineration contributes to air pollution in Kano teaching hospitals (Korfii et al., 2026). However, no study to date has systematically classified the categories of incinerators in use across the three tiers of hospitals in Kano Metropolis, examined their operational status, or documented the operational procedures under which incineration occurs. The present study addresses this gap.

The study draws on institutional theory to frame the analysis. The theory holds that organizational behavior, including the choice of technology, responds to institutional pressure, resource availability and concerns about legitimacy (DiMaggio & Powell, 1983; Suchman, 1995). Tertiary hospitals tend to command more money, more specialized staff and closer regulatory attention, which put advanced technology within reach. Primary and secondary facilities, working with tighter budgets, often cannot make the same choices. On this aim, incinerator technology should track hospital level fairly closely with the higher tiers more inclined toward advanced systems, that is why Incinerator categories,

operational performances and status as well as healthcare tier is a study worth researching.

The article addresses three objectives:

i. To identify the categories of incinerators currently used by government healthcare facilities in Kano Metropolis;
ii. To examine the operational status of these incinerators; and
iii. To test whether incinerator category varies systematically across hospital levels (primary, secondary, tertiary).

Literature Review and Conceptual Framework

Healthcare Waste Management: Global Context

Healthcare waste has become a global concern because of its capacity to spread infection, release toxic pollutants and contaminate the surrounding environment. WHO (2020) puts the hazardous share of healthcare waste at roughly 15%, covering infectious, toxic and radioactive material. Segregation and treatment infrastructure in low- and middle-income countries (LMICs) is often too weak to keep this material out of the municipal waste stream, exposing waste handlers, scavengers and nearby residents to risk (Singh et al., 2022).

Incineration Technology: Categories and Operational Requirements

Incineration remains widely used, especially in LMICs, because it destroys pathogens and cuts waste volume substantially. WHO (2019) groups incinerators into several categories by design, operating temperature and pollution-control capacity:

i. Double-chamber pyrolytic incinerators — operate at 800–1200°C with a post-combustion chamber; designed for infectious waste; capable of minimizing smoke and odours.
ii. Single-chamber furnaces with static grates — simpler, batch-operated units; lack flue-gas treatment; suitable only where air pollution is not a concern.
iii. Rotary kilns — operate at 1200–1600°C; capable of treating hazardous and cytotoxic waste; require flue-gas treatment.
iv. Locally constructed brick incinerators — low-technology units; no pollution-control infrastructure; commonly used in resource-constrained settings.

Safe incineration depends on several operating conditions: minimum combustion temperatures (typically ≥850°C for infectious waste), adequate residence time (≥2 seconds in the secondary chamber), and sufficient turbulence for complete combustion, and air pollution control devices (APCDs) such as scrubbers and filters (WHO, 2019; Bdour et al., 2007).

Hospital Hierarchy and Technology Adoption: A Neglected Dimension

Despite extensive documentation of incinerator technology in LMICs, the literature has paid limited attention to how hospital hierarchy shapes technology adoption; a significant gap, given how much primary, secondary and tertiary facilities differ in:

i. Financial resources-tertiary hospitals tend to have larger budgets and better access to donor funding.
ii. Technical capacity-tertiary facilities employ specialized staff, such as biomedical engineers and environmental health officers, capable of operating and maintaining advanced technologies.
iii. Regulatory oversight-tertiary facilities are more likely to face accreditation requirements and environmental regulation.
iv. Waste volume and composition-tertiary hospitals generate larger volumes of infectious and hazardous waste, creating economies of scale for advanced treatment technologies.

Institutional theory helps explain these differences. DiMaggio and Powell (1983) describe organizations converging on similar structures and technologies under coercive pressure (regulation), mimetic pressure (copying successful peers) and normative pressure (professional standards). Tertiary facilities likely face the strongest coercive and normative pressure to adopt advanced technology, while primary facilities often lack the resources to respond even where the pressure exists. Figure 1 sets out the theoretical framework used here.

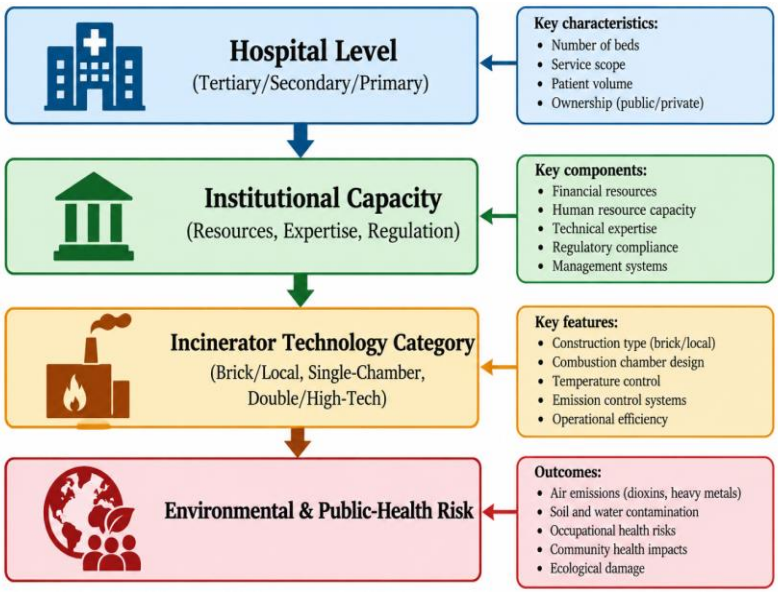

Figure 1: Theoretical framework

Empirical Evidence from LMICs

The picture that emerges from the LMIC literature is remarkably consistent: incineration remains the treatment method of choice across most low- and middle-income countries, yet the incinerators actually in use are overwhelmingly low-technology units that fall well short of international design standards. What is newer is the accumulation of systematic reviews and multi-country assessments that allow the research to see the pattern more clearly than the earlier single-site studies permitted. This section works through that evidence by region starting with global, Asian, African and Nigerian, before turning to what has and has not been studied in Kano.

Global and Cross-Cutting Evidence

Several recent reviews cast a wide net over healthcare-waste treatment in LMICs. Kenny and Priyadarshini (2021) surveyed current management methods and their global health effects, and their conclusion is sobering: incineration continues to dominate despite well-documented environmental and occupational hazards, largely because the alternatives are seen as too costly or too technically demanding for most facilities. Cook et al. (2023) took a different angle, conducting a systematic scoping review of occupational and public-health risks arising from every stage of the waste chain; generation, storage, treatment and disposal. Their synthesis singles out sub-standard incineration as a recurring source of exposure to toxic emissions and ash residues, with waste handlers and nearby communities bearing the greatest risk. Singh et al. (2022) reached the same conclusion in their review of sustainable medical-waste management, observing that the gap between what is recommended and what is actually done persists across most LMICs.

Two studies deserve particular attention for their focus on technology itself rather than practice. Zhao et al. (2021) assessed medical-waste disposal technologies in China across energy, environmental and economic dimensions, and their findings confirm what many have suspected: advanced incineration and non-burn alternatives perform better environmentally but demand capital and operational capacity that most facilities simply do not have. Quttainah and Singh (2024) approached the problem from a different direction, applying a Grey-based ranking method to identify the barriers that keep sustainable healthcare-waste management out of reach; financial constraints, weak regulatory enforcement and inadequate technical capacity topped their list. These studies make an important point: the technology gap in LMICs is not just about equipment. It is embedded in institutional, financial and governance conditions, precisely the terrain this study examines.

Asia

Ahmad et al. (2019) conducted a life-cycle assessment of hospital solid-waste treatment alternatives in Swat District, Pakistan. In Bangladesh, Tabassum et al. (2026) assessed medical-waste generation, workforce safety and segregation practices in Rajshahi City; their finding that more than half of the workers surveyed (56%) had received no training in handling hazardous waste, and that 54% worked without safety equipment, speaks to the broader pattern of neglect that accompanies low-technology incineration across the region. That study focuses on occupational safety rather than incinerator technology, but it illustrates the same underlying problem. The Chinese assessment by Zhao et al. (2021), discussed above, offers a useful counterpoint from East Asia: even where advanced technologies are available, their uptake depends on institutional and economic capacity.

Africa

Southern Africa has produced some of the most systematic evidence on this question. Ramodipa et al. (2026) reviewed healthcare risk-waste treatment practices and policy gaps in South Africa, and their finding is striking: despite a relatively developed regulatory framework, treatment infrastructure remains uneven and incineration is frequently sub-standard. Chisholm et al. (2021) surveyed medical-waste management across African developing countries more broadly, documenting widespread reliance on open burning, low-technology incineration and uncontrolled landfilling, with little in the way of pollution-control infrastructure. The earlier site-specific studies fit this pattern: Rogers and Brent (2006) found clinical-waste incinerators in Gauteng, South Africa, that were poorly maintained and leaking uncontrolled emissions, while Ketlogetswe et al. (2004) described locally built incinerators in Botswana that were largely in poor working order. In West Africa, Adu et al. (2020) reported that Ghana still relies mainly on incineration, most of it through sub-standard units with no pollution controls at all. These regional findings give a direct comparator for the Nigerian situation.

Nigeria

Within Nigeria, the evidence points in the same direction. Adama et al. (2016) measured heavy-metal concentrations in hospital incinerator bottom ash that exceeded landfill disposal limits, and Owoade et al. (2020) traced moderate but worsening contamination in soils around medical waste dumpsites in Ile-Ife. The most comprehensive recent synthesis is that of Ezeudu et al. (2022), whose review of healthcare-waste management across Nigeria confirms that incineration remains the dominant treatment technology, that most facilities rely on sub-standard units, which segregation practices are weak, and that regulatory enforcement is inconsistent. Importantly for this study, Ezeudu et al. (2022) explicitly identify a gap in facility-level, technology-specific evidence; precisely the gap this study addresses.

Three findings run through all of this literature. First, incineration remains the dominant healthcare-waste treatment technology across LMICs, despite its documented environmental and health risks. Second, the incinerators actually in use are predominantly low-technology units; brick, single-chamber, or otherwise sub-standard, lacking pollution-control infrastructure. Third, and perhaps most importantly, the persistence of low-technology incineration is not simply a matter of equipment scarcity; it reflects deeper institutional, financial and governance constraints. What the literature has not done, however, is treat incinerator technology itself as an object of analysis. Studies tend to compare treatment methods as categories of incineration versus autoclaving versus open burning, rather than disaggregating incinerator categories, operational status and procedural conditions. That is the gap this study addresses in the Kano Metropolis context.

Kano-Specific Evidence: Management Practices without Technology

Research on healthcare waste in Kano State has grown considerably over the past decade, but it has remained almost entirely focused on management practices such as segregation, handling, storage, transportation and disposal behaviours, rather than on the technology of incineration. Reading through this literature, one notices a consistent

pattern: studies examine what healthcare workers do with waste, but not what happens inside the incinerators those workers use, nor what types of incinerators exist across the healthcare hierarchy.

Two national-level studies provide useful context. Ezirim and Agbo (2018) assessed how healthcare-waste management quality varied across Nigerian states and facilities, including Kano State, as part of a national policy intervention; their analysis documents measurable improvements in waste-handling practices across six states. Of particular relevance here, they note that the Institute of Human Virology Nigeria distributed incinerators to 19 tertiary health facilities nationwide, and that the Federal Government provided high-temperature incinerators at selected tertiary facilities. Critically, they observe that incinerators were primarily available in tertiary health facilities, while secondary and primary facilities continued to rely on open-air burning and waste burial. This finding establishes the foundational premise that incinerator technology is unevenly distributed across the healthcare hierarchy in Nigeria. But Ezirim and Agbo (2018) do not examine the specific categories of incinerators in use, their operational conditions, or their procedural management within any single state, and they do not identify which Kano facilities received what technology.

Gage et al. (2016) offer a complementary perspective from their analysis of facility readiness across five Nigerian states, including Kano. Their readiness index incorporates access to incinerators as a criterion, and their findings are stark: fewer than 10% of surveyed health facilities, spanning comprehensive health centres, public primary healthcare centres, health posts, dispensaries and patent medicine vendors, disposed of contaminated waste by incineration. This confirms that incineration is a minority practice at lower tiers, reinforcing the pattern of hierarchically concentrated technology. Yet the study was designed to assess maternal-delivery readiness, not incineration technology; incinerator access appears only as one component of a composite index, and no information is provided on incinerator type, condition or operational procedure.

The most substantial body of Kano-specific research concerns management practices at individual facilities. Yakubu, Bello and Tsiga-Ahmed (2023) examined adherence to recommended waste-management practices among healthcare workers at Murtala Muhammad Specialist Hospital, a secondary facility in Kano. Their study documents practices relating to segregation, handling and disposal but does not analyse the incinerator serving the facility, its category or its operational status. Similarly, Imam, Sani and Sani (2019) and the follow-up study by Sani et al. (2021) assessed knowledge, attitude and practice relating to biomedical waste management in surgical theatres of selected hospitals in urban Kano. These studies contribute valuable evidence on the behavioural dimensions of waste handling, but they treat incineration as a peripheral backdrop rather than the object of analysis; incinerator type, condition and procedure remain unexamined.

At the primary-care level, Rn and Yahaya (2014) provided a case study of hospital waste-management practices in primary healthcare centres in Fagge Local Government Area, Kano State, focusing squarely on management practices, waste generation, segregation, storage and disposal within a single local government area. Omoleke et al. (2021) offer a more recent and methodologically rigorous assessment of medical-waste management at primary healthcare centres in a north-western Nigerian state, documenting poor practices and fragmented governance. Danjuma et al. (2026) extend this line of inquiry with an assessment of knowledge, attitude and practices among primary healthcare workers in Bichi Local Government Area, Kano State.

Muazu et al. (2026) examine the effects of solid-waste management on public and environmental health in Kano Metropolis more broadly. None of these studies, however, examines incinerator technology or the operational conditions under which incineration occurs; the incinerator, where present, remains a black box.

The closest existing evidence comes from Ibrahim and Liman (2025), who evaluated biomedical waste-management practices at Aminu Kano Teaching Hospital (AKTH), a tertiary facility. Their findings are directly relevant: they report that 85% of waste at AKTH is disposed of through incineration and 15% through open burning, and, critically, they identify that the hospital relies on a single, outdated incinerator without a scrubber system for emission control, deviating from modern standards and posing health risks. They call for immediate investment in advanced disposal technologies, including upgrading incinerator technology with emission controls. This is the closest existing evidence to the present inquiry, but it is a single-facility study: it does not compare incinerator technology across hospital tiers, does not classify the incinerator by category (brick/local, single-chamber, double-chamber), and does not examine the operational procedure of incineration at the facility. The finding that AKTH's incinerator lacks a scrubber is significant but isolated, but it raises the question of how many other facilities in Kano Metropolis operate under comparable or worse conditions, a question the study cannot answer.

Korfii et al. (2026) add a further dimension through their assessment of air-pollutant distribution patterns and potential health risks in hospitals across three north-western Nigerian states, including Kano. Their study identifies medical-waste incineration as a contributing factor to air pollution within hospital environments, alongside diesel generators and waste-burning practices, and confirms that a teaching hospital in Kano was purposively selected for environmental assessment. This work establishes the environmental health stakes of incineration in Kano and provides ambient air-quality evidence. However, its focus is on pollutant concentrations rather than incinerator technology; the incinerators themselves are treated as undifferentiated emission sources, and no attempt is made to classify them by type, assess their operational status, or examine their procedural management.

Three observations emerge from this synthesis of Kano-specific research. First, there is a clear and consistent pattern of scholarly interest in healthcare-waste management practices such as segregation, handling, storage, transportation and disposal, at both national and Kano-specific levels. Second, where incineration appears in this literature, it appears as one disposal method among several, not as the primary object of inquiry; incinerators are mentioned, counted, or treated as emission sources, but rarely examined as technological artefacts with categories, conditions and procedures. Third, the few studies that come closest to the present inquiry: Ibrahim and Liman (2025) at AKTH, and Korfii et al. (2026) on air quality, are single-facility or single-dimension studies that do not systematically compare incinerator technology across the healthcare hierarchy.

Identified Research Gaps

Four gaps emerge from this review, and together they justify the present study.

The first is a lack of hierarchical analysis. Most studies treat healthcare facilities as a homogeneous category, without

examining how technology adoption varies across hospital levels. The Kano-specific literature is no exception: studies focus on individual facilities (Yakubu et al., 2023; Ibrahim & Liman, 2025) or on a single tier of care (Rn & Yahaya, 2014; Omoleke et al., 2021; Danjuma et al., 2026), without comparing incinerator technology across primary, secondary and tertiary facilities.

The second is that no study has systematically classified the categories of incinerators in use across the three tiers of hospitals in Kano Metropolis, whether brick/local, single-chamber, double-chamber, or high-technology systems. While Ezirim & Agbo (2018) establish that incinerators are unevenly distributed across the healthcare hierarchy nationally, and Ibrahim and Liman (2025) document the specific case of AKTH, the full distribution of incinerator categories across Kano Metropolis remains unmapped.

The third is that no study has examined the operational status of these incinerators, whether they are functioning, non-functional, or under repair, despite evidence from AKTH that at least one tertiary facility operates an outdated unit without emission controls (Ibrahim & Liman, 2025).

The fourth is that no study has documented the operational procedures under which incineration occurs, loading practices, ash handling, pollution-control infrastructure, maintenance regimes and record-keeping, despite the environmental health stakes established by Korfii et al. (2026).

These gaps matter because the existing literature cannot answer the questions that policy and practice most urgently require. If incinerator technology is unevenly distributed across hospital tiers, as Ezirim & Agbo (2018) and Gage et al. (2016) imply at the national level, then the scale of that unevenness in Kano Metropolis remains unquantified. If some incinerators are non-functional or lacking pollution controls, as Ibrahim and Liman (2025) document at AKTH, then the extent of this problem across the metropolis is unknown. And if operational procedures vary across facilities, as the broader LMIC literature suggests (Rogers & Brent, 2006; Ketlogetswe et al., 2004; Adu et al., 2020), then the procedural determinants of environmental performance in Kano remain unexamined.

The present study addresses these gaps by systematically classifying incinerator technology across the three tiers of government hospitals in Kano Metropolis, documenting operational status through direct observation, and testing whether incinerator category varies systematically with hospital level.

MATERIALS AND METHODS

Research Design and Sampling

The study used a multi-method, cross-sectional design across Kano Metropolis, northern Nigeria. The sampling frame was established through a reconnaissance survey conducted prior to the main data collection. This preliminary survey covered government hospitals across Kano Metropolis and found that most did not operate an incinerator of their own: many smaller facilities were found to contract their healthcare-waste incineration out to larger hospitals, while others disposed of waste through open burning conducted at night. Hospitals without their own incinerator, or without a designated incinerator site, were excluded from further consideration on this basis. The reconnaissance survey, carried out in June 2024 through direct observation and questionnaire administration, identified twelve facilities operating an incinerator or a designated incinerator site; of these, nine were selected for the main study because they additionally had a long-established history of functional, on-site incineration and the highest patient volumes among government facilities in the metropolis, and therefore generated the largest and most environmentally consequential healthcare-waste stream.

The nine facilities were purposively selected and justified based on four criteria, applied through the reconnaissance survey and subsequent screening: a functional incinerator, or designated incinerator site, had to be present; the facility had to be among the highest-volume government providers by patient throughput; the sample as a whole had to represent all three hospital tiers; and the facility had to be willing to take part.

This gave two primary-care sites (Imam Saminu Ibrahim Primary Healthcare Centre [ISI-PHC], Tarauni Primary Healthcare Centre [T-PHC]), four secondary-care sites (Murtala Muhammad Specialist Hospital [MMSH], Infectious Diseases Hospital [IDH], Abubakar Imam Urology Centre [AIUC], Sir MuhammaduSunusi Specialist Hospital [SMSSH]) and three tertiary sites (Aminu Kano Teaching Hospital [AKTH], National Orthopaedic Hospital Dala [NOH Dala], Muhammadu Abdullahi Wase Teaching Hospital [MAWTH]).

Because selection prioritized facilities with an established history of functional, on-site incineration, the nine study sites represent a best-case subset of Kano's government facilities, both federal and state-run, with respect to incinerator infrastructure. The majority of state government hospitals in the metropolis, which the reconnaissance survey found to contract incineration out or rely on nighttime open burning, were excluded from the sampling frame altogether and may present a considerably more severe picture than the one reported here. Nighttime open burning in particular is likely to generate higher, more poorly controlled emissions than even the brick/local incinerators described in Section 4, since it occurs with no combustion chamber, no temperature control and no oversight at all. Notably, three of the nine selected facilities were nonetheless found, during subsequent field observation, to be experiencing technical faults that had rendered their incinerators temporarily out of service (Section 4.4), despite having been identified as functional at the point of selection; facility authorities reported that repairs were actively underway in each case.

The research treats this not as inconsistency but as a substantive finding: it indicates that incinerator functionality can deteriorate over a relatively short period even at facilities initially screened for operational status, and the study discussed it as part of the functional-operational paradox in Section 5.3.

Of the nine sampled facilities, two; AKTH and NOH Dala are federally administered; the remaining seven are state government facilities, including MMSH, which was established in 1976 and is the oldest of the nine facilities sampled, consistent with the long-established-incineration criterion used in selection.

Purposive sampling rather than random sampling suited and justified the aim, since the study was interested in how technology varies across hospital levels rather than in producing a population-representative estimate. That choice limits how far the findings generalize to every government facility in Kano, but covering all three tiers still gives a reasonable cross-section of the healthcare hierarchy. Questionnaires, ethical approval, observation form and checklists as well as facility selections were validated by team of experts and professionals.

Scope and Study Area Description

Kano Metropolis spans eight metropolitan Local Government Areas, including Fagge, Nasarawa, Dala, Kano Municipal, Gwale, Tarauni, Kumbotso and Ungogo, covering roughly 500 km² between about 8° and 9°E and 10° and 12°N (Figure 2). It sits within the Sudan savannah zone, with a warm tropical climate: mean monthly temperatures run from about 21°C to 31°C, and rainfall across the metropolis averages around 800 mm a year. Soils are predominantly ferruginous or lateritic, ranging from loamy sand to clay, and both surface water and groundwater are shaped by local geology, climate and human activity. These conditions matter here because they influence how ash-derived contaminants move and accumulate once released into the environment.

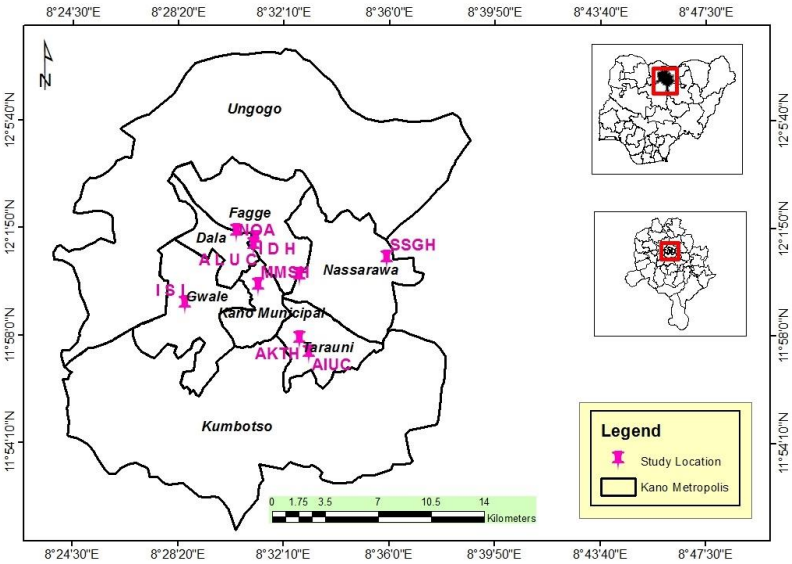

Figure 2: Study area and sampled healthcare facilities. Source: GIS & Cartography Lab, Geography Department, Bayero University Kano, 2025.

The study concentrates on incineration and healthcare-waste management at government facilities across the three hospital tiers covering incinerator categories, operations and performances. Questionnaires and observation work ran through 2024-2025. Private facilities, waste quantification beyond the study's own variables, air pollution and wastewater components, seasonal variation, and laboratory analysis of bottom ash or soil all fall outside its scope.

Data Collection Protocols

Two instruments were used: a structured questionnaire, completed by 131 environmental health officers, waste handlers and facility engineers (N = 131 valid responses), and a direct physical-observation checklist. The questionnaire's internal consistency was acceptable (Cronbach's $\alpha = 0.78$–0.82), clearing Nunnally's (1978) benchmark of $\alpha \geq 0.70$, and the observation audits showed good inter-rater agreement (Cohen's $\kappa = 0.84$).

Statistical Analysis

Analysis was carried out in IBM SPSS Statistics and Python (SciPy/Statsmodels). A Pearson chi-square test of independence was run on a 3 × 3 contingency table of hospital level against reported incinerator category ($df = (3-1)(3-1) = 4$). Because three of the nine cells, a third of the table, had expected frequencies below 5, the study cross-checked significance with Monte Carlo exact permutation tests and two non-parametric rank correlations, Spearman's ρ and Kendall's τ_b, and calculated Cramer's V to gauge the strength of the association, interpreted against conventional effect-size benchmarks (Cohen, 1988).

Unit of Analysis and Statistical Interpretation

The 131 questionnaire responses analyzed in Section 4.3 were nested within only nine facilities: several staff members at each site were describing the same physical incinerator, so individual responses are not fully independent of one another. Treating them as independent observations, as is common practice in this literature, risks understating standard errors and overstating significance. We therefore report the individual-level chi-square, Cramer's V and rank correlations as a description of how consistently staff within and across facilities characterized incinerator category, rather than as a stand-alone, independent facility-level inferential test. The substantive claim that incinerator technology tracks hospital tier rests primarily on the facility-level pattern reported in Table 2 and on the consistency between self-reported category and direct observation (Sections 4.4–4.5); the individual-level statistics should be read as corroborating and exploratory. With only nine facilities, a facility-level inferential test (for example, Fisher's exact test on the 3 × 3 table implied by Table 2) would be too underpowered to interpret meaningfully, and we do not report one for that reason. Confirming the tier association at the facility level, with adequate statistical power, will require larger, multi-site replication.

Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and was approved in 2024 by the Bayero University Kano School of Postgraduate Studies Ethics Committee, the Aminu Kano Teaching Hospital (AKTH) Ethics Committee, the National Orthopedic Hospital Dala (NOH Dala) Ethics Committee, and the Kano State Hospitals Management Board Ethics Committee. Informed consent was obtained from all questionnaire respondents prior to participation; the observational component involved no identifiable human participants. Full details are provided in the Institutional Review Board Statement and Informed Consent Statement at the end of the manuscript.

RESULTS AND DISCUSSION

Incinerator Categories

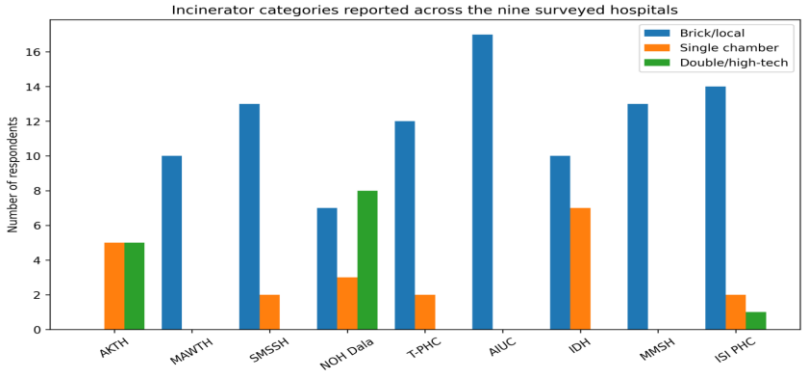

Figure 3: Distribution of incinerator categories across the nine surveyed hospitals
Source: Fieldwork, 2025.

Brick or locally designed incinerators dominated the sample, accounting for 96 of the 131 responses (73.28%, 95% CI: 65.2–80.4%). Single-chamber units made up 21 responses (16.03%, 95% CI: 10.2–23.4%), and double-chamber or other high-tech units accounted for the remaining 14 (10.69%, 95% CI: 5.9–17.3%).

Facility-Level Patterns

Patterns varied considerably from one facility to the next. AKTH reported the highest share of double/high-tech units (50%), whereas MAWTH, AIUC and MMSH reported brick/local units exclusively (100%). NOH Dala's profile was more mixed: 44.44% double/high-tech, 38.89% brick/local, 16.67% single-chamber. Both primary facilities leaned heavily toward brick/local units too, though ISI-PHC reported a small share of double/high-tech units (5.88%).

Grouped by tier, secondary facilities relied almost entirely on brick/local (85.48%) and single-chamber (14.52%) units, and primary facilities were similarly dominated by brick/local designs (83.87%). Double-chamber/high-tech units, by contrast, were concentrated in tertiary facilities, accounting for 34.21% of tertiary responses and driven mainly by AKTH and NOH Dala.

Statistical Association between Hospital Level and Incinerator Category

Table 1: Statistical Evaluation of Incinerator Technology Category by Hospital Level (N = 131)

Metric / Statistical Test	Value	df	p-value / Effect Size / Interpretation
Pearson Chi-Square (χ^2)	34.75	4	$p < .0001$; Cramer's V = 0.364 (Moderate-to-Strong)
Spearman Rank Correlation (ρ)	0.375	—	$p < .0001$; Significant positive monotonic association
Kendall's Tau-b (τ_b)	0.345	—	$p < .0001$; Significant ordinal trend across tiers

Note: N = 131 questionnaire responses across 9 facilities. Three cells (33.3%) had expected counts < 5; significance was verified via exact permutation testing and ordinal rank correlation.

Hospital type and reported incinerator category were significantly associated at the individual-response level, $\chi^2(4, N = 131) = 34.75$, $p < .0001$, Cramer's V = 0.364, with both rank correlations pointing the same way: Spearman's $\rho = 0.375$ ($p < .0001$) and Kendall's τ b = 0.345 ($p < .0001$). As noted in Section 3.5, however, these 131 responses are clustered within nine facilities rather than fully independent, so we treat this result as descriptive of how consistently incinerator category was reported within and across facilities rather than as a stand-alone facility-level inferential test.

The more direct evidence for the tier association comes from the facility-level pattern in Table 2, read alongside the observational evidence in Sections 4.4–4.5. Of the nine sampled facilities, seven show a reported category consistent with the general tier gradient described above (higher-tier facilities running equal- or higher-technology units than lower-tier facilities); MAWTH (tertiary, brick/local) and ISI-PHC (primary, double/high-tech, though under repair at the time of observation) are the two exceptions, and we return to both in Section 5.3 as evidence of decoupling between formal technology tier and operational reality.

Transparency Note

A third of the table's cells had expected frequencies below 5, which can make the Pearson chi-square anti-conservative, so we checked it against Monte Carlo exact permutation tests and the two rank correlations reported above; all three approaches agreed on the direction and significance of the individual-level pattern. This cross-check addresses small expected cell counts, but not the clustering issue discussed in Section 3.5, which is a separate limitation addressed there.

Operational Status

Table 2: Operational Status of Incinerators by Facility

Facility	Level	Incinerator Category	Operational Status
AKTH	Tertiary	Double/high-tech	Functioning
NOH Dala	Tertiary	Double/high-tech	Functioning
MAWTH	Tertiary	Brick/local	Functioning
IDH	Secondary	Single-chamber	Functioning

Facility	Level	Incinerator Category	Operational Status
AIUC	Secondary	Brick/local	Functioning
SMSSH	Secondary	Brick/local	Functioning
MMSH	Secondary	Brick/local	Under repair
T-PHC	Primary	Brick/local	Under repair
ISI-PHC	Primary	Double/high-tech	Under repair

Note: "Under repair" indicates a unit that was experiencing a technical fault at the time of data collection, rendering it temporarily inoperable; facility authorities reported that repairs were actively in progress at each of the three affected sites. Source: Fieldwork, 2025.

Site visits confirmed that AKTH and NOH Dala kept a tighter handle on their incinerator environments, secure containment, ventilation, washing facilities and restricted access were all in place. Several other facilities, by contrast, ran locally built systems with manual loading, no scrubbers, no routine emission testing and no waste registers. Notably, MMSH, whose incinerator was under repair at the time of the visit, was also, by a clear margin, the highest-volume facility in the sample in terms of both patient turnout and healthcare-waste generation, a combination we return to in Sections 5.3 and 5.5.

Facility-Level Physical Observations

Physical inspection of the nine sampled incinerator sites revealed significant operational vulnerabilities.

i. Primary healthcare centers (T-PHC, ISI-PHC): incinerators were unlined brick structures built locally, with no chimney and no temperature gauge, effectively amounting to open burning. ISI-PHC did have a double-chamber unit on site, but it was under repair for a technical fault at the time of the visit, a reminder that owning the technology is not the same as being able to use it continuously.

ii. Secondary hospitals (MMSH, IDH, AIUC, SMSSH): these facilities ran single-chamber or brick units with passive stacks; ash containment pits were left unsealed and none had flue-gas scrubbers. MMSH's incinerator, moreover, was down for repair at the time of the visit, with facility authorities reportedly working to resolve the fault (see Table.2).

iii. Tertiary hospitals (AKTH, NOH Dala, and MAWTH): AKTH and NOH Dala had double-chamber diesel-fired incinerators, but maintenance backlogs and the cost of fuel often pushed staff back onto older brick units as a fallback. MAWTH, despite its tertiary status, ran a brick/local unit outright — a sign that even within a tier, practice can diverge sharply.

Discussion

Theoretical Interpretation of Structured Heterogeneity

The pattern linking hospital tier to incinerator category, visible in the individual-level statistics ($\chi^2 = 34.75$, df = 4, $p < .0001$, Cramer's V = 0.364) and, more directly, in the facility-level distribution in Table 2 is consistent with institutional theory as applied to an urban health system, though we treat it as exploratory for the reasons set out in Section 3.5. Read this way, the variation in technology does not look scattered at random. We describe it instead as structured heterogeneity: a gradient along which institutional power, capital and regulatory compliance appear to set equipment standards across the healthcare hierarchy.

Both rank correlations back this up (Spearman's $\rho = 0.375$, Kendall's $\tau_b = 0.345$, both $p < .0001$): the odds of finding higher-technology incinerators rise steadily from primary through secondary to tertiary care. That fits DiMaggio and Powell's (1983) argument that organizations under stronger coercive pressure (regulation), mimetic pressure (copying successful peers) and normative pressure (professional norms) tend to adopt more advanced technology.

Tertiary facilities sit at the top of this hierarchy, feel these pressures most keenly, and have the resources to act on them.

Comparison with International Evidence

This echoes what has been reported from South Africa (Rogers & Brent, 2006) and Botswana (Ketlogetswe et al., 2004), where small-scale incinerators commonly lacked basic pollution controls, and from Ghana, where Adu et al. (2020) found incineration still the dominant treatment method, mostly through sub-standard units without emission controls. Where our results go further is in showing that deficiency in Kano is not uniform but patterned: tertiary facilities have the institutional capacity to procure double-chamber units that align with WHO (2019) guidelines, while primary and secondary facilities remain tied to brick/local designs.

That complicates the usual assumption that low-technology incineration simply reflects national resource constraints. The variation within Kano suggests institutional factors operating at the facility level matter just as much, and the structured heterogeneity described here may well hold in other LMIC cities where tiered healthcare produces the same unequal access to resources and oversight.

The Functional-Operational Paradox

Field observation surfaced what we call a functional-operational paradox: having an incinerator, even an advanced one, is no guarantee that it is available for use at any given time. Three facilities: MMSH (secondary), T-PHC (primary) and ISI-PHC (primary), had incinerators down for repair when we visited, sidelined by technical faults that facility authorities were reportedly working to resolve, and ISI-PHC's affected unit was a double-chamber/high-tech installation. Procuring equipment without the maintenance capacity to keep it consistently running, in other words, can create the appearance of treatment coverage that is not always actually available.

The MMSH case makes the stakes concrete. Among the nine facilities studied, MMSH generated the largest volume of healthcare waste and received the highest patient turnout, yet it was operating a brick/local unit that was, at the time of the study, out of service. MMSH is also the oldest of the nine facilities, established in 1976, so the finding is not that a new or hastily equipped facility struggled to keep its incinerator running; it is that the metropolis's longest-established, highest-volume facility could not. The facility with the single greatest waste burden in the sample therefore also had, at that moment, no working treatment capacity of its own, precisely the combination of high waste generation and unreliable treatment that this study set out to investigate.

This pattern is well captured by the institutional concept of decoupling. Meyer and Rowan (1977) argued that organizations often adopt formal structures, including capital equipment, to satisfy external legitimacy demands while day-to-day operations remain only loosely tied to those structures;

later work suggests decoupling can persist even where implementation looks complete on paper, because operational practice continues to answer to resource and maintenance realities that the formal structure does not capture (Bromley & Powell, 2012). ISI-PHC's double-chamber unit sitting idle for repair, and MAWTH's continued reliance on a brick/local unit despite its tertiary status, both fit this description: the formal technology tier and the operational reality have come apart. Read through this lens, institutional capacity looks necessary but not sufficient for adoption to translate into consistently functioning equipment, legitimacy pressure may explain what gets procured, while maintenance funding, procurement cycles, repair turnaround times and historical legacy explain whether that procurement remains usable in practice.

Operational Vulnerabilities across Tiers

The tier-specific vulnerabilities documented in Section 4.5, the unlined, open-burning brick units at primary level, the unsealed ash pits and absent scrubbers at secondary level, and the maintenance backlogs that push even AKTH and NOH Dala back onto legacy brick equipment at tertiary level, all point the same way. None of the pollution-control infrastructure that Bdour et al. (2007) treat as essential for holding proper temperature and residence time is reliably present, and construction quality itself often falls short. Across the three tiers, environmental performance in Kano appears to hinge on how technology choice, construction quality, maintenance and institutional capacity interact, rather than on any single factor alone.

Implications for Environmental and Public Health

With brick/local units accounting for 73.28% of the sample, the environmental and public-health stakes are considerable. These units have no secondary combustion chamber, no particulate filters and no scrubbers, so they release dioxins, furans and heavy metals into the air and leave behind hazardous bottom ash, consistent with the health risks documented in early assessments of incinerator emissions more broadly (Allsopp et al., 2001).

That a third of surveyed facilities' incinerators were out of service for repair at the time of the study compounds the risk further, since the fallback, open burning emits more than even a poorly controlled incinerator would.

MMSH is the clearest illustration of this risk, for the reasons discussed in Section 5.3: waste volume and treatment reliability are exactly the two factors that jointly determine environmental exposure, and at MMSH they moved in opposite directions at the same time. This suggests that maintenance prioritization should weight not only tier but also facility-specific waste volume; a high-turnout secondary facility with a temporarily disabled incinerator may pose a greater immediate risk than a lower-volume tertiary facility running an older but working unit.

Addressing this will take more than buying better equipment; maintenance, residue management and regulatory oversight need to be part of the same treatment chain

Conclusion

The research in conclusion demonstrated that the use of incinerators is a major challenge in Kano metropolis across healthcare facilities. The major problem is the way hospitals not keying into the idea of advance use of modern incinerators neither are the hospitals paying close attention to the risks involved from poor clinical incineration practices. Healthcare-waste incineration in Kano metropolis is dominated by low-technology brick units (73.28%) while single-chamber units for (16.03%) and the double-chamber systems (10.69%) that do exist are concentrated almost entirely in tertiary hospitals. Three of the nine facilities had incinerators out of service for technical repairs at the time of the study, regardless of tier or technology installed, and repairs were reportedly underway at each facility. This suggests that procurement and operational practice can diverge even where formal technology tier would predict otherwise, institutional capacity appears necessary but not sufficient for adoption to translate into consistently available treatment. This pattern is consistent with, though not conclusively established by the individual-level statistics reported in the research and the facility-level evidence which together support institutional theory's prediction that resource availability, regulatory pressure and legitimacy concerns shape technology adoption across a healthcare hierarchy.

Recommendations

Based on these findings, the research recommended a three-point level-differentiated action plan;

Differentiated Technology Standards

Tertiary facilities should be required to retrofit pollution-control equipment, given that their technical capacity and waste volumes justify investment in advanced incinerators fitted with air pollution control devices (APCDs). Primary and secondary facilities need something simpler to operate and maintain standardized, maintainable non-burn or improved dual-chamber designs. Non-burn options such as autoclaves or microwaves may suit primary facilities particularly well, since they avoid combustion emissions altogether. The study recommends that the Ministry of Health, working with state environmental protection agencies, set tier-specific technology standards and procurement guidelines, specifying minimum design requirements such as secondary combustion chambers for incinerators and temperature monitoring across all thermal treatment units.

Maintenance and Operational Budgeting

Maintenance funds should be ring-fenced within facility budgets, and repair turnaround times should be prioritized by facility waste volume rather than by tier alone. That a third of incinerators in this sample were out of service for technical repair, including a double-chamber unit at ISI-PHC and, most consequentially, the unit at MMSH, the sample's highest-volume facility, shows both how easily equipment develops faults without dedicated maintenance funding and how uneven the consequences of a given repair delay can be. A fault at a high-turnout facility such as MMSH creates a larger treatment gap, in waste-volume terms, than an equivalent fault at a lower-volume facility, even if both are nominally the same tier. Hospital budgets should carry a specific line item for incinerator maintenance, released quarterly against completion reports, with state health authorities auditing maintenance spending, operational status and repair turnaround time each year, and with the highest-volume facilities in each tier flagged for priority response when faults occur.

Regionalized Central Waste Treatment

Central, off-site treatment hubs deserve consideration for primary facilities, where units like those at T-PHC and ISI-PHC currently amount to unmonitored open burning and its attendant risks. A hub equipped with an advanced incinerator or non-burn technology could treat waste from several primary facilities at once, gaining economies of scale and

bringing regulatory oversight within reach. A pilot serving three to five primary facilities, fitted with either a double-chamber incinerator with APCDs or an autoclave system depending on waste composition, would be a reasonable place to start in Kano Metropolis, alongside transport protocols to keep handling safe in transit.

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